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ABSTRACT

The origins of inquiry activities are discussed in this historical review and assessment of science textbooks. Approximately 80 texts (dated from 1822 to 1910) were analyzed specifically for inquiry teaching strategies. No significant patterns were detected, either by subject or time, which could support an identifiable birth of inquiry. After 1880, there were consistently more "experiments" included in the reviewed texts but there was no evidence of student initiated studies or problems. Science texts and laboratory manuals in the eary 1900's were highly structured and were devoted to large quantities of verbal explanations. However, several texts which were prepared specifically for teachers led to the speculation that inquiry was still not a prominent aspect of science teaching. Inquiry appeared to have been implemented in some classrooms around the turn of the century, but was certainly not a common methodology. Tables are included which present information on (1) percentages of inquiry activities found in textbooks based on the stages of Lee's taxonomy of teaching style examples, (2) percentages of inquiry activities by subject matter areas, and (3) citings from specific texts of potential evidence of inquiry based activities. (ML)

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AN EXAMINATION OF SCIENCE TEXTS FROM EARLY AMERICA TO THE 1900s FOR EVIDENCE OF INQUIRY ORIENTED PRESENTATIONS

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This is a review and assessment of approximately 80 historical textbooks which were analyzed specifically for inquiry teaching strategies.

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Introduction

Inquiry oriented instruction has been strongly advocated as a significant and necessary instructional strategy for educating contemporary students. National attention was focused on science education through the Woods Hole Conference which was immediately followed in the 1960's by the rapid succession of a large number of federally-funded science curriculum projects in elementary and secondary science. Although motives and rationales differed, a common thread was the desire to educate students at all levels in the nature of science. The spectrum of opinion varied primarily between structured experimentation and open inquiry, but there was little disagreement about immersing students in materials, concepts, ideas, and activities which would permit experiencing the dynamics of the scientific enterprise as opposed to the static exposure to lectures and reading materials.

It is a reasonable assumption that current activities have historical roots. New ideas presumably can't burst from vacuums but rather are new wood braced and nourished by a foundation of older growth. As Clitus remarked to Alexander, "It is true that you have conquered, but it was with your father's soldiers."[22]

Considering this premise, it seemed reasonable to review the "old wood" of early science texts in an attempt to locate evidence of new growth as demonstrated by potential inquiry activities or suggestions.

Although inquiry as a methodology is difficult to define in precise terms, the intent of its meaning as used in this paper will be to include any of the categories, 3-9, identified by Addison Lee's taxonomy of teaching style examples. These categories were presented in the 1978 Association for the Education

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of Teachers in Science (AETS) Yearbook[3] (see categories in Table 1).

Insert Table 1 here

Textbooks and Inquiry Instruction, 1822-1910

In reviewing over eighty texts from the George Peabody Library's archive collections at Vanderbilt University, the amount of dust which had to be removed suggested that whatever popularity they may have experienced in the past was no longer apparent.

No significant patterns were detected in this review, either by subject or time, which could support an identifiable birth of inquiry. After 1880, there were consistently more "experiments" included in the texts reviewed, but much of this inclusion was related to didactically implemented demonstrations. There was no evidence of student initiated studies or problems, but about three-fourths of the texts did include level two activities (set methods and observations with prescribed results). This compares with about twenty-five percent of the texts written prior to 1880. Half of all texts reviewed were essentially books of reading about science, but only about 5% of the texts between 1900-1910 were entirely reading texts. Table 1 illustrates the levels of inquiry appearing in the texts reviewed.

When the texts reviewed were subdivided into general subject matter areas by titles, some differences were noted by subject matter area and time. However, no high level inquiry activities were noted in any text. Table 2 illustrates this information.

Insert Table 2 here

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Where potentials exist for higher levels of inquiry, especially in physics, the nature of the discipline is more responsible than a specific planned effort to involve inquiry. For example, problems sited often require some application which goes beyond knowledge and comprehension.

It is impossible to state with certainty how teachers used the books reviewed. Statements and examples were given, however, which could have been used to illicit inquiry-type strategies in a few presentations. The following summaries in Table 3 provide illustrations of several authors' intentions which could have provided an environment for inquiry.

Insert Table 3 here

Examples from the fifteen books selected for a more detailed presentation reflect exceptions rather than norms.

Cotting (1822),[13] Bland (1830),[9] and Blakewell (1834)[7] were more deviant when compared with contemporaries than were the authors of about 1890-1920. The format they used and the quality of their questions were equal to or superior to the authors of this latter period. Their contemporaries, however, were more likely to prepare reading texts than were authors around the turn of the century. It is unclear whether Cotting, Bland, or Blakewell actually desired students to perform activities and make inferences or draw conclusions based upon their own findings. Potentially, this format was possible, but it is also likely that, in Aristotelian fashion, they sat under a large tree and contemplated the answers.

Avery's three texts were anomalies when compared to the works of authors during the 1860's-1880's.[5] Although he recommended many excellent experiments which provided ample potential for even sophisticated inquiry, his

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practice of fully explaining everything that happened (or should happen) negated open inquiry for most activities. His admonition to seek accuracy and not permit students to "waste time" following incorrect procedures suggests that activities were prescribed for predetermined purposes and correct answers were expected.

It is very probable that Avery's text of 1895 exemplifies all activity oriented texts for at least the next fifteen years. Laboratory activities were provided, student involvement was requested, and questioning was frequent. Convergent and "correct" answers, however, were usually expected. Inquiry levels 4 (guided interpretation of data) and 5 (demonstrations with inquiry questions) were possible but it is unlikely that true inquiry was anything but rare or non-existent.

T. M. Goodeve completed a series of thirteen science texts in applied mechanics at Royal School of Mines (London) in 1870.[15] In the appendix, it was noted that the report of the Public Schools Commission and the Schools Inquiry Commission "have shown that there is still a want of a good Series of Textbooks in Science, thoroughly exact and complete."[15] Although the books are filled with artistically attractive diagrams, the series is essentially a reading series infused with many mathematical formulas. No "experiments" are recommended and no questions are suggested for guiding instruction.

Anthony and Brackett's 1897 text for elementary physics is similar.[2] It is filled with reading material infused heavily with mathematical formulas but has no teaching or activity suggestions.

Physics texts of the early 1900's carried the imprint of "lists" of experiments which had been recommended by some university or association. Cheston, Dean, and Timmerman, three New York high school teachers, stated in their 1903 text:

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> "All experiments required by College Examination Board of Middle States and Maryland, by Harvard, and by New York Board of Regents are included."[11]

This compilation of "experiments" included a total of 78 separate activities and it was recommended that a student complete half of these in a one-year course. It needs to be recognized that the term "experiment," as used by early authors, would be more appropriately represented by the term "activity" or perhaps "demonstration." In the introduction, the authors explain the role of the student as follows:

> "After the data required have been collected by careful observation, each pupil should be expected to draw from these facts some general principle relevant to the declared object of the experiment...not expected to discover Nature's laws."[9]

The laboratory had charts to be completed, diagrams, a few low level questions, and required "conclusions" for each activity.

Absence of inquiry or discovery oriented methodology may be suspicioned from Coleman's comments in his New Lab Manual for Physics:

> "These experiments should be regarded as a limited inquiry into the facts at first hand, not as a source of adequate data for generalizations by the pupils...what he really does is to perform an experiment which, within a fair degree of accuracy (defined as 2% elsewhere), illustrates or exemplifies the law and he does this in order that he may better understand it."[12]

Texts reviewed for the early 1900's show a marked transition. For example, Gage (1902),[14] Adams (1908),[1] and others have specific questions which accompany each activity, and several were probably above the comprehension

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level as defined by Bloom's taxonomy. Adams recommends the rather classic mode of writing up lab activities: 1) Purpose, 2) Apparatus, 3) Operations, 4) Discussions, 5) Conclusions, and 6) References. He further states that a student's "ability to make neat, clear, legible, and accurate record of anything is an acquisition to be desired." Gage suggested that one-third of class time should be devoted to laboratory practices, especially to satisfying the requirements of Harvard University.

Bailey's botany text of 1906 was considerably more attractive than any of the physics or physical science texts reviewed and was amply illustrated with photographs and diagrams. Several interesting activities were included which at first appeared as providing opportunity for inquiry oriented instruction. For example, radish seeds were to be germinated and parallel lines drawn on the growing stem to illustrate growth differentiation. This activity certainly provides an opportunity for students to hypothesize, measure, collect data, interpret it, etc., but a cursory review of questions suggested by Bailey shows most at the knowledge level with perhaps a few possibilities for comprehension or application. The judgment that inquiry, if it existed, was probably accidentally provided for, is supported by the fact that pages 282-340 are devoted to a detailed plant taxonomy key for use by students.[6]

Several generalizations may be gleaned from reviewing science texts and laboratory manuals which were written at the turn of the century. They were highly structured and devoted to large quantities of verbal explanations. Most were reasonably attractive and had many diagrams, and physical science texts were amply provided with mathematical formulas, some quite sophisticated. When compared to Goodeve's 1876 textbook series or Rolfe and Gillet's Handbook of Natural Philosophy of 1869,[21] there were few significant differences in

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general appearance and format. One important difference, however, was the addition of questions which could be used for instruction and the obvious recommendation for student participation in laboratory experiences. Coleman exemplified this change by stating in 1908, "that laboratory work is an important part of a course in elementary physics is no longer an open question." [12]

Several texts, which were written later and prepared specifically for teachers, lead to the speculation that inquiry was still not a prominent aspect of science teaching. Kendall and Mirick's text on The Elementary School Subjects published in 1915, did not even list science in an index that devoted five lines to tests for reading and eighteen lines to spelling. Hygiene was a topic but included statements about brushing teeth properly, drinking coffee and tea, high heels, and a host of other facts.[18] Pieper and Beauchamp's Teacher's Guidebook for Everyday Problems in Science, published in 1927, presented science as something of practical life value and discussed motors, health habits, water, and a variety of other topics. But they did pose problems and legitimate inquiry appeared in several activities.[20] Brownell and Wade, in 1925, recommended that the science laboratory be used for teaching science methods and exposing students to the appropriate scientific attitudes. Their admonition to use basements, attics, unused storerooms, or any other available space for science laboratories yields revealing insight into the conditions of laboratory facilities existing in schools. Many of these conditions occurred after the number of students attending high school dramatically increased in the early 1900's and lab rooms were confiscated for classroom space.[10]

It would be easy to speculate that inquiry oriented instruction has never really been integrated into schools, and criticisms, even post-Woods Hole,

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would help support this belief. Inquiry does seem to have been initiated in some classrooms around the turn of the century, but was certainly not a common methodology. Trustworthy data aren't yet available for determining the extent of implementation of the spirit of science in classrooms, but ample complaints to the contrary may be found.

A Prologue

An attempt to assign the precise advent of the first example of inquiry, even for levels two or three in Lee's taxonomy, would be certain to offend those of a prior decade or perhaps even a prior century. Precisely identifying the time when "experiments" gave way to experimentation is equally difficult.

In all probability, the lower levels of inquiry as Lee describes them were accidental strategies in some 19th century American classrooms. More examples may have occurred in the early 1900's. It cannot be ignored, however, that the Thirty-First Yearbook of the National Society for the Study of Education (1932) was largely devoted to complaints about didactic methods and inconsequential science teaching.[19] Although this latter criticism was directed at high school science teaching, most high school courses of this era were patterned after college courses and texts were authored by college professors. It hadn't been more than a decade or so that the differentiation between high school and college was a major problem and concern.

Martin Haberman implied that legacies are neither neat nor do they begin and end with critical events or memorable dates.[16] This appears to be an accurate assessment of inquiry oriented science instruction.

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Table 1

Evidence of Inquiry in Textbooks

1822 - 1910

9.	Problem-centered activities Define problem and variables. Formulate hypothesis. Design experiment. Test hypothesis.	NONE
8.	Experiments with set methods which lead to open-ended outcomes and hypothesis formulation.	NONE
7.	Student-designed experiments to test hypothesis.	NONE
6.	Experiment with set methods to test hypothesis. Students asked to find answers to "key questions" asked.	NONE
5.	Teacher demonstration as focus for inquiry questioning.	1880-1910 1822-1880
4.	Data provided: Students guided to interpretation.	1881-1910 1822-1880
3.	Lecturing with some inquiry questioning.	1881-1910 1822-1880
2.	Experiments, set methods and observations with prescribed results.	1881-1910 1822-1880
1.	Traditional lecturing.	1881-1910 1822-1880

Potentials Present—
No Direct Evidence
Of Implementation

10 20 30 40 50 60 70

PERCENT

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Table 2

Subject Matter Areas and Inquiry Activities

Subjects Time *(1822-1910)

Inquiry Stages	Nat.Philos. 1	Nat.Philos. 2	Phy.Sci. 1	Phy.Sci. 2	Physics 1	Physics 2	Chemistry 1	Chemistry 2	Botany 1	Botany 2	Physiology 1	Physiology 2
9												
8												
7												
6												
5	(0)	(12.5%)			(0)	(25%)			(0)	(14%)		
4	(0)	(0)	(0)	(11%)	(0)	(0)			(0)	(0)		
3	(12.5%)	(12.5%)	(0)	(11%)	(0)	(50%)	(14%)	(0)	(14%)	(28%)		
2	25%	25%	11%	44%	12.5%	62.5%	14%	14%	0%	43%	0%	0%
1	37.5%	12.5%	22%	22%	0%	25%	57%	14%	43%	14%	50%	50%
											(4 books)	

* 1 = 1822-1880
2 = 1881-1910
(. . .) Potential for this level of inquiry--
No firm evidence for implementation

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Table 3

Potential Evidence of Inquiry in Historic Texts

Author/Date	Comments
Cotting (1822): [13]	Reviews of "experiments" followed by some guiding questions, mostly knowledge and comprehension; Format: experiment/demonstration — explanation — questions; example: Why is it that deep lakes do not freeze in winter? How does the atmosphere dissolve water? (p. 68)
Bland (1830): [9]	A list of trigonometrical, hydrostatic, and optical problems; problems associated with Newton's Laws; most could be application level; well done.
Blakewell [7] (1834):	Interesting questions throughout text: Why does a metal handle become hotter than a wooden handle? (Give an experiment to illustrate); How can we measure the heat of different bodies? (p. 21); What do you understand by an elastic fluid? (p. 70); Why are gravel walks less affected by dew than grass? (p. 78); Can the images produced by the magic lantern be magnified without being made indistinct? How? (p. 215).
Atkinson [4] (1863):	Excellent diagrams and illustrations, such that students could have "tried out" ideas or practiced activities; no specific questions or suggestions for activities, however.
Rolfe and Gillett (1869): [21]	Appendix which "contains problems and notes which give a full account of the apparatus needed for the book, and directions for performing difficult experiments."

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Table 3 (continued)

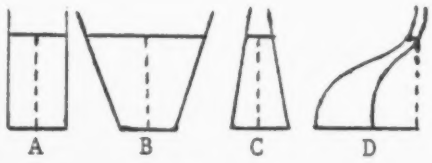
Author/Date	Comments
Goodeve (1876): [15]	Almost no good examples of inquiry, although he wrote thirteen texts; reported that the Public Schools Commissions "have shown that there is still a want of a good Series of Text-Books in Science, thoroughly exact and complete," (preface); excellent diagrams but few questions or activities; one example of an interesting exercise is found on p. 29. EXERCISES 1. The areas of the bottoms of vessels A, B, C, and D (Fig. 24) are equal. The vessels have the same depth and are filled with water. (a) Which vessel contains the most water? (b) On the bottom of which vessel is the pressure equal to the weight of the water which it contains? (c) How does the pressure upon the bottoms of vessels A, B, C, and D compare, respectively, with the weight of the water in them?  FIG. 24
Avery (1881): [5]	Questions presented at the end of each chapter: A body weighs 1440 lbs. at the surface of the earth; how far above the surface will it weigh 90 lbs.? (p. 181); Find the weight in sulphuric acid (sp. gr. 1.75) of a piece of lead weighing 150 g. and having a sp. gr. of 11, (p. 182); A ball projected vertically upward, returns in 15 seconds to the place of projection. How far did it ascend? (p. 437); Explain the difference between noise and music (p. 439).
Avery (1884): [5]	Many excellent "experiments" suggested with detailed diagrams, but complete explanations are provided in the text; no questions were addressed to students for 240 "experiments." Most of those experiments, if presented without explanations, could have been excellent for inquiry activities if students were permitted to draw conclusions or hypothesize. It would probably have been rare for a teacher to use the text this way, unfortunately.

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Table 3 (continued)

Author/Date	Comments
Avery (1395): [5]	Benefits of lab work for the "cultivation of habits of accuracy of observation, formation of systematic methods, and the development of an ability to reason from observed particulars to general laws," (p. 7). Most evidence depicts a didactic approach, but an occasional question challenges thinking during the book's 158 "experiments;" i.e., "If, in the system mentioned, the rope is attached to a moveable block, what power will raise a ton?" (p. 145). Avery's 1895 text does provide more possibilities for student participation, but he states that the "teacher (should) get to each pupil at short intervals to check gross errors at the beginning, and thus prevent much waste of time." (p. 7).
Hinds (1902): [17]	Students are required to explain the results of activities (demonstrations): there are questions after each activity, but most questions are at the level of comprehension.
Cheston, Dean, Timmerman [11] (1903):	Seventy-eight experiments, and students should complete at least 35. "After the data required have been collected by careful observation, each pupil should be expected to draw from these facts some general principle..." (p. 3); diagrams, charts to complete, some questions, and "conclusions" expected after each activity; essentially convergent with correct answers expected.
Bailey (1906): [6]	Students requested to observe growth of roots of radishes (p. 13), draw lines on stem and observe growth (p. 18); very attractive pictures and illustrations; most questions at knowledge level, and pp. 282-340 contain a plant key for making a "collection."
Bergen and Davis (1907): [8]	Despite statement that the "student is to interrogate mainly not the instructor; not the manual, but the plant itself (p. iii), the test is factually presented with an extensive part devoted to "making a collection."

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Table 3 (continued)

Author/Date	Comments
Adams (1908): [2]	Activities should be written according to a prescribed format: 1) Purpose, 2) Apparatus (Used), 3) Operations, 4) Discussion, 5) Conclusions, 6) References (p. 11); the "ability to make a neat, clear, legible, and accurate record of anything is an acquisition to be desired" (p. 9); conclusions often required application of knowledge as well as comprehension. Heavy application of mathematics.
Coleman (1908): [12]	"that lab work is an important part of a course in elementary physics is no longer open to question" (p. 3); ...work is well done if it is not in error by more than two per-cent...what he (student) really does is to perform an experiment which illustrates or exemplifies the law;" a carefully designed series of questions is used to guide the student in using apparatus, and answers to questions for "experiments" are not given; example: after using a prism, the student is asked, "From the observed phenomena, do you find the critical angle at a glass-water surface greater or less than at a glass-air surface?"

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